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A New Way to Measure Stratosphere-Troposphere Coupling in Observations and Climate Models

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This project explores new intercomparisons between reanalysis data and CMIP5 models, and introduces a new way to quantify stratosphere-troposphere (S-T) coupling through the movement of mass in and out of the polar cap at different levels, as measured by mean polar cap pressure at fixed geopotential heights. The aims of this project are to investigate how mass movement is related to variations in stratospheric circulations, such as the states of the wintertime polar vortex; discover whether stratospheric processes amplify the tropospheric signal, and by how much; assess how mass movement is represented in climate models of varying complexity; establish whether different model parameterisations produce different S-T coupling outcomes; and identify any projected changes as a result of climate change. The results of this investigation will be beneficial for furthering our understanding of S-T coupling processes, and improving medium-range forecasting skill through use of stratospheric data.

This work uses data from ERA-interim reanalysis and CMIP5 climate models. The data has been zonally averaged, and geopotential height values from the data are interpolated across pressure levels to produce pressure values at a set of defined heights. From a composite of deseasonalised data of the polar cap, defined as 65-90 degrees, it was discovered that a maximal stratospheric anomaly of increased pressure occurs between 12 and 20 km, with a similar structure in both the northern and southern hemispheres. Concurrently, this influx of stratospheric mass seems to induce polewards air flow in the troposphere, a so-called “tropospheric amplification”, creating an area of stored atmospheric mass in the column of air above the pole.

This phenomenon is present in the wintertime during the period of ERA-interim, and is recreated qualitatively in CMIP5 models; a similar shape and magnitude are clearly reproduced, and models with a high top (> 48 km) produce the most realistic recreation. These occurrences follow a pattern which links to the states of the polar vortex, with positive amplification corresponding to a weak polar vortex, and vice versa. This shows similarity to the Northern and Southern Annular Modes, as a weak polar vortex is indicated by a negative NAM. A “tropospheric amplification factor” can be defined to quantify the anomalous pressure increase, which can be directly compared to the NAM/SAM index.

This work forms part of a three-and-a-half year PhD project with potential links to the ongoing SPARC Reanalysis Intercomparison Project (S-RIP).